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Tomato Spraying IN PENNSYLVANIA

Technical

Tomato foliage and fruit September 25, 1949, when sprayed with a 1-2-100 mixture of ziram and tribasic copper sulfate. This spray treatment gave the highest proportion of mature fruit in the first four pickings.

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Readers Please Note

The discussion and summary of the material contained in this bulletin appeared as Bulletin 531P of this Station.

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Tomato Spraying in Pennsylvania[*]

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SEVERE AND WIDESPREAD ATTACK by late blight during the years 1946 through 1948 aroused general interest in the spraying of tomatoes because of the threat to extensive acreages of high quality crops. Broad efforts have since been made to evaluate new fungicides and to devise better adapted spray treatments for the control of tomato diseases. Improved control of the different foliage blights and fruit rots now is possible while certain detrimental effects to the crop which had often accompanied tomato spraying, such as retarded growth, reduced set of fruit, and delayed harvest, have become largely avoidable.

Experimental work in this connection has been facilitated by the cooperation of state experiment stations serving important tomato growing regions and by the ready assistance of canners and farmers.[1] Many tomato growers have adjusted cultural practices to regular programs of disease control, particularly the spacing of plants to permit the use of power machinery to apply fungicides and insecticides. In 1949, fungicides were applied to 85 per cent of the tomato acreage in Pennsylvania.

It now is fitting to record and summarize relevant experimental data with the view of comparing the specific effects of available fungicides upon both the crop and the various diseases. Although most of the results herein have been obtained in Pennsylvania, the averages of certain data assembled by the cooperation of workers in interested state experiment stations are included for corroboration *(21, 22)*.

PRINCIPAL DISEASES

Late Blight

This disease is caused by the fungus *Phytophthora infestans*, one of the downy mildews. The conspicuous characteristics of the disease and its extreme destructiveness became familiar to tomato growers during the serious epiphytotics of 1946, 1947 and 1948. The disease starts as scattered, dull or brown-green, water-soaked lesions usually near the tips of leaves at the top of plants. With rain or heavy dew, lesions enlarge and multiply and the progress of blight becomes markedly rapid. With continued dampness, the whitish downy mycelium of the fungus becomes visible on the under sides of infected leaf areas. When the weather clears and dries, the progress of the blight is arrested while already infected tissues turn black.

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1/ The author is indebted to the management of the Hershey Estate, Hershey, Pa.; to Norman J. Brubaker, Sheridan, Pa.; and to Daniel Glick, Smoketown, Pa., for cooperation in providing suitable ground for experimental plots.

Both young and mature fruits also become infected, this being manifest by brown lesions which spread over the surfaces. These lesions soon may encompass whole fruits which finally decay throughout, figure 1. The extent of loss depends upon how early in crop development the disease begins and how long weather favorable to its spread continues. Losses approaching 100 per cent are possible, table 6.

As a rule, late blight does not appear until the approach of fall when night temperatures become 60 degrees Fahrenheit or lower, which enables the spores to germinate readily. This usual late appearance gives the disease its common name. To attain epiphytotic extent, late blight requires a considerable period, such as a week or 10 days, of subnormal temperature accompanied by above normal rainfall. The fungus does not withstand freezing and hence does not survive the winter in environments undergoing this condition.

Frequency of late blight.—The recent outbreaks of late blight on tomato are the most extensive on record in the Atlantic Coast and the Central Plain states. This relates not only to the huge losses but also to the number of consecutive years in which the disease has persisted. In Pennsylvania, the period has reached five years. The next prior outbreak of serious extent dates back to 1915 to 1917. The crop loss in 1917 was 10 per cent according to notes of Orton (27). Only traces of late blight upon tomato have been observed during the intervening years.

Fig. 1.—Late blight infection of tomato fruit.

The future prevalence of late blight on tomato is mostly conjectural, but more frequent occurrences may arise from certain changed cultural factors. Much of the new tomato acreages in Pennsylvania is in mountain valleys of comparatively high elevation where the low temperature required for development of the pathogen is reached earlier in the season than in lowlands. It was in the mountain valleys that the greatest damage occurred during 1946, 1947, and 1948.

The introduction of late blight by means of infected transplants from southern seed beds was general in 1946. The disease was carried in this manner first from southern Florida to Georgia, and then from the latter region to fields of various northern states. When the causal organism is placed in a favorable environment at the start of the growing season, it is likely to cause greater damage than otherwise. The volume of traffic in transplants is large and provides a ready channel for the spread of the pathogen from a region where it may not be destroyed by freezing or drying from one year to another.

Loss by late blight in Pennsylvania during 1947 was 60 per cent less than in 1946, partly on account of better control and partly because of a later start of the disease. There was no evidence of disease introduction from the South by means of transplants. The chief source of inoculum appears to have been potato tubers infected by the tomato race of *P. infestans*. Among 25 collections of tubers from storage in different parts of the state, Mills (25) found 13 to contain the tomato race, although all of these occurred in table rather than in seed stock.

Mills (24) points out that late blight on tomato commonly follows its appearance on potato by approximately a month when weather favors the disease. He presents data to show that the potato race can adapt itself to tomato and acquire the same degree of virulence that it exhibited on potato, finally becoming indistinguishable from a virulent tomato race. Tomato and potato fields are in proximity throughout Pennsylvania so that transfer of the causal organism from one crop to the other is generally possible.

In 1948, there was no evidence that *P. infestans* was introduced by infected southern grown plants, but in 1949 some cases were found.

Another method by which *P. infestans* apparently overwinters is upon greenhouse tomatoes as the fungus has been found upon this crop in late winter and early spring in a few cases in Pennsylvania.

Early Blight

The cause of this disease is *Alternaria solani*, a fungus which is generally present in cultivated soils and can survive winter freezing. It attacks potato as well as tomato, developing first upon the older leaves. The lesions vary in breadth from 1 to 20 or more millimeters, are brown and commonly show concentric zones or target-like markings which are caused by successive stages of advancement of the pathogen in the leaf tissues.

Fig. 2.—Early blight lesions on fruit of tomato.

Early blight may develop early or late in the growing season depending upon the abundance of inoculum, weather conditions, and the current susceptibility of the host. *A. solani* is a relatively weak parasite and is especially favored by impaired plant tissues for initial invasion. Plants lacking proper nutrition or growth, having been temporarily arrested by drouth or mechanical injury, exhibit particular susceptibility upon return of moist conditions. The disease, as a rule, generally affects aging plants in the fall, both stems and leaves becoming profusely spotted. Remaining fruit may show conspicuous lesions, especially in cracks and about the point of stem attachment, figures 2 and 4.

The chief ill effects of early blight when it attacks early in the season are premature defoliation, table 9. The fruit then is undersized, improperly ripened, and poor in quality. The damage can become serious. When transplants carry infection, the organism may invade stem wounds and cause girdling, resulting in considerable loss of stand.

Anthracnose

This is the most important fruit spot and is caused by the fungus *Colletotrichum phomoides*. This pathogen lives over winter in the soil persisting upon old, incompletely decayed parts of the tomato plant.

The disease becomes progressively worse as the culture of tomatoes is continued. Infected fruit exhibit small, slightly sunken, water-soaked, circular spots which are darker than surrounding tissues. These spots gradually become more depressed, attain breadths of a half inch or more, and ultimately show concentric markings, figure 3.

Initial infections by *C. phomoides* occur when tomato fruit are comparatively small and green, but the lesions do not enlarge nor become discernible until ripening is well advanced (*7, 16*). The disease appears to spread after picking but this is mostly enlargement of early infections to the point of visibility. After maturity, infections spread into deep tissues and may involve the whole fruit. Anthracnose entails serious losses for both the grower and the canner, the former from culling and lowered grade and the latter from discarded fruit after shipment and poor quality of product.

Septoria Leaf-spot

Another frequent cause of premature defoliation is leaf-spot caused by the fungus *Septoria lycopersici.* Beginning symptoms consist of numerous, roughly circular, water-soaked lesions scattered over the surface of leaves. Later these spots show dark margins and gray central areas containing many tiny black flecks. These flecks are the spore-containing bodies. The disease usually attacks in warm wet weather

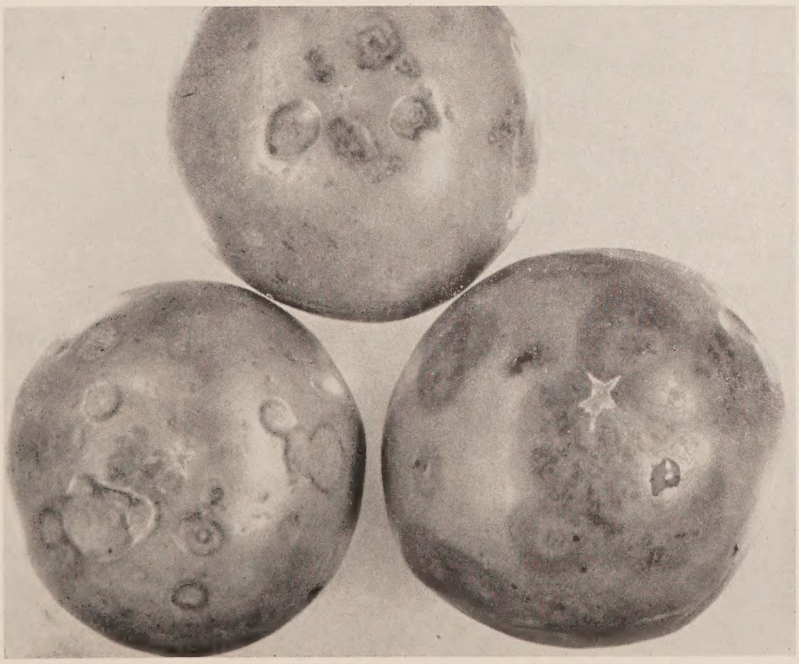

Fig. 3.—Anthracnose on mature fruit of tomato.

when plants are heavily set with fruit. Loss of foliage then results in much improperly matured fruit.

Leaf-spot often causes serious damage in the Middle Atlantic and Central Plain states during wet seasons. The pathogen is most active when temperatures range from 60 to 80 degrees Fahrenheit. In Pennsylvania, the disease is largely limited to territory near Lake Erie and to counties of the southeast, the central mountain area being too cool for the ready sporulation of the fungus. Leaf-spot has not been concerned in the present experiments, but results are considered applicable because spray treatments effective against late blight also check leaf-spot.

PREVIOUS WORK

The first use of a fungicide upon tomato was in New Jersey by Halsted (*9*) who, in 1895, tested bordeaux to control Septoria leaf-spot. In 1906, Smith (*31*) recommended bordeaux to control late blight upon tomato in California. From these early beginnings to the recent era of combined schedules of organic and fixed copper fungicides, a great deal of experimental work has been conducted in all important tomato growing states, most of it being directed against leaf-spot. Bordeaux soap, soda and potash bordeaux and deka copper mixture received trials as well as 4-4-50 bordeaux; then after 1931 the various fixed copper compounds were tested.

Although many instances of large increases of yield were reported (*2, 5, 6, 28*), the long period of experimental work did not lead to any regular practice of tomato spraying, although there was some tendency toward this in the more elevated sections of Virginia and West Virginia where late blight, as well as leaf-spot, was a frequent threat. The main obstacles were: (1) the practice was not profitable when diseases were unimportant; (2) reduced yield, particularly with bordeaux, was probable in a dry season; and (3) potential gain was often offset by delayed harvest and frost damage.

Meanwhile, concurrent experimental work (*28*) showed that prevention of Septoria infection of tomato seedlings was an important measure in checking leaf-spot in the field. Tomato seed may be contaminated by various disease organisms and requires treatment with hot water at 122 degrees Fahrenheit for 25 minutes to destroy them. After hot water treatment, seed should be cooled and soaked in new improved ceresan for 5 minutes to forestall damping-off. This fungicide is mixed with water at the rate of one ounce to a gallon. Further measures to prevent Septoria infection of seedlings are treatment of the seed bed soil with steam and the spraying of seedlings with a fixed copper fungicide.

The foregoing control measures are equally important in preventing seedling infection by *A. solani.*

Fig. 4—Defoliation by early blight with no spray treatment, September 25, 1949; early blight lesions occur on the remaining fruit.

Injury by Bordeaux

Although injury by bordeaux had been observed upon both fruit and vegetable crops by various workers who noted such ill effects as dwarfing, defloration, russeting and depressed yield, Horsfall et al (*13, 14*) were first to investigate the real nature of the trouble. They analyzed varied types of injury upon tomato in an effort to find why the fungicide did not give yields commensurate with disease control. They compared the action of low-lime and high-lime bordeaux with lime alone and with red cuprous oxide and copper oxychloride, two fixed copper compounds. They found the types of injury to be interrelated, caused in part by copper toxicity and in part by accelerated transpiration and hardening effects resulting from calcium. Much of the harm to tomato by bordeaux, including dwarfing, excessive transpiration and defloration, appeared to be related directly or indirectly to the alkalinity of the mixture. Similar harm was done occasionally by acid sprays but not by neutral sprays.

Knowledge of the factors involved in bordeaux injury brought about a reduction in both the copper sulfate and the lime content of mixtures recommended for tomato, a 6-3-100 mixture being advised usually, although an 8-4-100 is preferable if late blight is severe. The likelihood of injury has become much less but is not altogether set aside as subsequent data will show.

Fixed Copper Compounds

An important era of experimental spraying (or dusting) followed 1931 when a group of scientists headed by Roberts (*29*) in the U. S. Department of Agriculture began investigation of fixed or insoluble copper compounds as possible substitutes for bordeaux. The so-called fixed copper fungicides are really slightly or slowly soluble. Investigation of these was carried out in cooperation with different chemical industries, who for the most part developed the various compounds. Several materials proved approximately equal to bordeaux in fungicidal capacity. At the same time they were much less injurious to host plants and hence were safer to use under dry conditions, or those favoring chemical injury.

The relative effects of several copper fungicides and bordeaux were compared by Keil (*15*) on The Pennsylvania State College farms during the comparatively dry season of 1938 when diseases were rather unimportant. The early tomato variety Penn State was grown for the spraying experiments. Data in respect to defloration, number of fruit set and yield are given in table 1. Treatments were replicated 6 times so that data could be analyzed statistically. All the fungicidal mixtures were in greater strength than those now advised.

All spray treatments resulted in significantly less blossoms per cluster than no treatment with the exceptions of copper hydro-40 plus microsulphur and copper oxychloride, table 1. The reduction caused by bordeaux is greater than that of any fixed copper by three to four fold. All treatments resulted in significantly less fruit per cluster than no treatment, but the loss in the case of bordeaux is three times that of any fixed copper. Four of the fixed copper compounds gave yields greater than no treatment, while bordeaux and two fixed copper compounds

Table 1.—Comparative effects of spraying tomato with certain fixed copper fungicides and bordeaux during a dry season, 1938*.

SPRAY TREATMENT	AVERAGE BLOSSOMS PER CLUSTER	AVERAGE FRUIT SET PER CLUSTER	MARKETABLE FRUIT PLUS OR MINUS THAT OF NO TREATMENT
	number	*number*	*tons*
No treatment	9.2	4.6	
Copper hydro-40, 8-100 plus microsulphur, 4-100	8.9	3.9	2.39
Copper oxychloride, 8-100	8.6	3.9	1.20
Copper compound-A, 5-100	8.2	3.8	1.03
Yellow cuprous oxide, 3-100	8.2	3.7	1.52
Bordeaux, 8-12-100	5.3	2.5	-2.52
Basic copper sulfate, 6-100	7.9	3.8	-0.20
Copper arsenate, 6-100	8.2	3.9	-0.59
Least significant difference	0.73	0.42	Not significant

*The data of this table are from the unpublished Masters thesis of Harry L. Keil, The Pennsylvania State College, 1939.

gave lower yields, that of bordeaux being less by 2.52 tons. This large reduction is doubtless due to the excess lime. The differences in average yield did not prove statistically significant.

The superiority of fixed copper fungicides over bordeaux in yield is shown from results obtained by Kirby and Burke (*20*) during the wet season of 1937 when early blight and Septoria leaf-spot were very prevalent. The yield for 8-8-100 bordeaux was approximately twice that of no treatment, but that of 2-100 red cuprous oxide was 2.5 times, and that of 6-100 copper oxychloride was 3 times that of no treatment.

Henderson (*10*) in Virginia compared 4-5-50 bordeaux with 4-100 tribasic copper sulfate and 1.5-100 yellow cuprous oxide during 1941 and 1942. These two fixed copper fungicides were tested both as sprays and as dusts. The diseases present included late blight, early blight, Septoria leaf-spot, and the leaf blight caused by *Stemphylium solani*. Profitable and significant results were obtained with all treatments. Henderson found no outstanding differences among the three fungicides in their capacities to control disease. In 1941, which was dry during the latter part of the growing season, bordeaux gave lower yields than the fixed copper materials, but in 1942, which was moist throughout the growing season, bordeaux gave the highest yields.

In a comparison of bordeaux mixtures of standard and reduced strengths and several fixed copper compounds, Walker et al (*34*) in Wisconsin did not obtain increases of yield great enough to be profitable. The important diseases were early blight and Septoria leaf-spot. It is probable that the shortness of the growing season in Wisconsin latitude makes profitable tomato spraying unlikely as time may be insufficient to mature all fruit. These investigators emphasize the factor of nutrition in the susceptibility of plants to early blight, and they were able to show experimentally that judicious fertilization of poor soils increased yields more than the application of fungicides under otherwise comparable conditions.

The unfavorable effects of bordeaux as compared with a fixed copper fungicide may be revealed more by early than by late varieties of tomatoes. Beach (*1*) compared the effects of 6-4-100 bordeaux with 4-100 tribasic copper sulfate upon the early variety Valiant, the midseason variety Stokesdale, and the late variety Rutgers during 1947. Both fungicides were applied 5 times at 10-day intervals. The fore part of the season was moderately dry while the latter part was wet and cool enough to promote severe late blight. Upon Valiant and Stokesdale, the number of fruit harvested per plant in the case of bordeaux was approximately 25 per cent less than in the case of tribasic copper sulfate. On these same varieties, the differences in yield between the two fungicides was close to 4 tons of salable fruit, table 2. Upon Rutgers, the difference between the two fungicides was 11 per cent in fruit number and less than a ton in yield. The degree of late blight control was much the same for both fungicides upon each variety.

Comparative data show that fixed copper fungicides are a definite improvement over bordeaux for safety or freedom from crop injury. Differences in fungicidal value against early blight and late blight usually are not significant when the better materials are considered. Extensive experimental tests have shown, however, that both the fixed copper fungicides and bordeaux are inadequate in the control of anthracnose. This fact prompted the testing of organic chemicals for possible fungicidal value in the hope that a material for use specifically against anthracnose would be found.

Development of Organic Fungicides

Investigation of organic chemicals as possible fungicides was begun by Roberts (*30*) and his associates shortly after their work upon fixed copper compounds was undertaken. Interest soon centered upon certain organic compounds which were being developed and tested as accelerators and anti-oxidants in the production of rubber products. Notable among these were the dithiocarbamates upon which Tisdale and Williams (33) as well as others were doing important preliminary work. Roberts and his associates clearly determined the fungicidal capacity of the methyldithiocarbamates. Of these compounds, ferric dimethydithiocarbamate and zinc dimethyldithiocarbamate proved particularly valuable, the former being called fermate and the latter zerlate by the manufacturer. Both of these fungicides are quite specific in their action against anthracnose and both have been widely tested upon fruit and vegetable crops. Upon tomato, zerlate has become the preferable material because it leaves no visible residue and surpasses fermate somewhat in anthracnose control.

In 1943, Dimond et al (*4*) described another valuable organic fungicide, sodium ethylene bis dithiocarbamate, which has become known

Table 2.—Comparative effects of bordeaux and tribasic copper sulfate upon different varieties of tomato, Centre County, 1947.

Variety and fungicide	Fruit harvested per plant	Salable fruit per acre	Late Blight on fruit
	number	*tons*	*per cent*
Valiant			
Bordeaux, 6-4-100	31	10.2	2.7
Tribasic copper sulfate, 4-100	41	14.4	4.3
No treatment	33	5.8	23.7
Stokesdale			
Bordeaux, 6-4-100	39	11.0	10.0
Tribasic copper sulfate, 4-100	55	15.8	9.2
No treatment	27	4.0	39.0
Rutgers			
Bordeaux, 6-4-100	40	12.6	16.5
Tribasic copper sulfate, 4-100	45	13.5	16.7
No treatment	29	3.8	59.0

as dithane. This compound has the distinctive characteristic of being soluble in water as prepared but becoming insoluble after drying upon foliage, thus assuring tenacity. Heuberger later found that the sodium compound could be reacted in the spray tank to form zinc ethylene bis dithiocarbamate through the addition of zinc sulfate. A dust formulation of this zinc compound is made and marketed under the trade name of dithane Z-78. A similar dust preparation of zinc ethylene bis dithiocarbamate is marketed under the trade name of parzate. Both dithane Z-78 and parzate are particularly effective against early blight and both follow closely behind zerlate in the control of anthracnose.

FUNGICIDES

The fungicides used in the present experiments are listed below with the inclusion of the chemical name, the common name, the manufacturer, and the strength of mixture in spraying. Since various producers of chemicals may eventually wish to prepare and market the same compounds, generally applicable common names become a convenience. The Subcommittee on Fungicide Nomenclature of the American Phytopathological Society and other interested cooperating agencies have selected suitable common names which have been registered with the Trade-Mark Division of the U. S. Patent Office. In the accompanying list, trade names which have been assigned previously by manufacturers are in parentheses following the common names.

The tribasic copper sulfate used in the recorded experiments may be regarded as a representative fixed copper fungicide since other brands of like material or certain other fixed copper compounds might

Table 3.—List of fungicidal chemicals, manufacturers, and spray mixtures.

CHEMICAL	COMMON AND TRADE NAME	MANUFACTURER	STRENGTH OF SPRAY MIXTURE
			lb./100 gal.
Zinc dimethyldithiocarbamate	ziram (zerlate)	E. I. du Pont de Nemours & Co.	2
Ferric dimethyldithiocarbamate	ferbam (fermate)	same	2
Manganese ethylene bis dithiocarbamate	none	same	2
Zinc ethylene bis dithiocarbamate	zineb (parzate)	same	2
Zinc ethylene bis dithiocarbamate	zineb (dithane Z-78)	Rohm & Haas Co.	2
Cuprous oxide	none (yellow cuprocide)	same	1.5
Tribasic copper sulfate	"tribasic" (same)	Tennessee Corporation	4
Copper-zinc compound	none (cop-o-zinc)	same	5
Copper-zinc-chromate compound	none (crag)	Carbide & Carbon Co.	2
Copper 8 quinolinolate	none (bioquin 1)	Monsanto Co.	1

have been used. The 6-3-100 bordeaux may be considered the standard of fungicidal value particularly against late blight. The discussion is largely limited to those fungicides which show a high degree of effectiveness against one or more of the mentioned tomato diseases, which give profitable increases of yield or have certain illustrative value.

SPRAY SCHEDULES

The review of previous work in tomato spraying reveals great variations in disease conditions in respect to year and locality. The variation relates to both the fungi present and to the severity of their attack. No single fungicide, moreover, is highly effective against all the diseases. One way of meeting this difficulty has been to devise different spray schedules, one for periods when late blight is imminent and another for periods when early blight and anthracnose are the chief diseases. Much of the recent experimental work has involved combined schedules in which a copper and an organic fungicide have been included. The copper fungicide has been intended mainly for the control of late blight and the organic mainly for the control of anthracnose. Such combinations make synergism possible in which the specific action of each fungicide against a particular disease is obtained. This generally results in better average control and higher yields than if a single fungicide is applied in a straight schedule.

Ziram and a fixed copper, (or bordeaux) have been applied experimentally in varied sequences. In one schedule, ziram and tribasic copper sulfate (or a fixed copper) have been applied alternately, starting and ending with ziram. In the following tables, this schedule is denoted by Z-C-Z-C-Z in which Z means ziram and C tribasic copper sulfate. This schedule has been tested in all cooperating states. In the schedule Z-Z-Z-C-C, 3 applications of ziram have followed by 2 or more of tribasic copper sulfate (or a fixed copper). Bordeaux is denoted by B when it is used instead of a fixed copper. When the sequence of application is not given, a straight schedule of the single fungicide is to be understood.

The reasons for the schedule Z-Z-Z-C-C, which appears adapted to most areas of Pennsylvania in late blight years, are several. Infections by *C. phomoides,* the fungus causing anthracnose, occur largely when tomato fruits are young, or as early as 10 days after they are set. Data concerning the period of infection have been published by Fulton (*7*) and by Kendrick and Walker (*16*). To prevent anthracnose, it appears most effective to apply ziram during the period of active vegetative growth and setting of fruit. Late blight, on the other hand, usually develops late in the growing season and hence a copper spray should comprise the late sprays. Copper fungicides, furthermore, are most likely to be injurious during active vegetative growth and blooming, which is the warmest part of the season, than at later periods. Ziram, and likewise zineb, cause little, if any, injury to flowers.

Combination mixtures of ziram and tribasic copper sulfate have been tested in spraying with no apparent adverse effect. Although it seemed at first that mixtures of these two chemicals might react too rapidly to permit application, or be otherwise unstable, definite evidence of this has not been noted in the Pennsylvania experiments. The fungicides were used during the same year in which they were manufactured. Combination mixtures of ziram and tribasic copper sulfate made with old materials or those of a previous year manufacture may develop brown discoloration upon standing a few hours according to observation of extension plant pathologists of The Pennsylvania State College. Whether such discolored mixtures are injurious to plants has not been ascertained. It may be advisable to limit combination mixtures to fresh fungicides.

A combination mixture of 1 pound of ziram and 2 pounds of tribasic copper sulfate to 100 gallons has been used in a straight schedule; also a 2-2-100 mixture. Such mixtures would have the advantage of simplicity for the grower since it involves no variation of formula. Early set of fruit would receive some protection against late blight before the dense growth of foliage prevents thorough coverage by spray.

In 1949, a sliding-scale schedule was tried in which ziram and tribasic copper sulfate had the following proportions in successive applications: first, 2-0-100; second, 2-1-100; third, 2-1-100; fourth, 1-2-100; fifth, 1-3-100; sixth, 0-4-100. This schedule was among the best in disease control and had no adverse effect.

Experimental Plots and Spray Application

Spraying experiments were conducted each year in two localities: Centre and Lebanon, or Lancaster, counties. The lay-out of plots was similar to that adopted by most cooperators conducting fungicidal tests upon tomatoes in different states. Each plot was 10 by 22 feet on which were set 10 plants arranged in 2 rows of 5 plants spaced 4 feet apart. Every treatment had five replications, one in each of five randomized tiers of plots. This lay-out gave aisles 6 feet wide in two directions between plants of separate plots.

The late variety Rutgers, most commonly used for canning in Pennsylvania, was grown. In Centre county, the soil on The Pennsylvania State College farms was sown with inoculum of *C. phomoides* a week before spraying began in order to assure uniform and heavy infestation by this fungus. The location was in a low, but well drained, area which was naturally prone to heavy dews. This favored the prevalence of both early and late blights. The plots in the other counties were on the farms of growers and reliance was placed on natural infestation for the prevalence of disease.

Fig. 5.—Tomato foliage on September 25, 1949, when sprayed with dithane Z-78. The plant was undesirably vegetative for the time of year. Although production was heavy, too great a proportion of the fruit did not mature.

A small engine sprayer capable of maintaining 250 to 300 pounds pressure was used to apply the fungicides. Applications were generally limited to five, the first being about six weeks after the plants were set in the field. Succeeding applications were made at 10-day intervals insofar as practicable. This first application required 160 gallons and the last 275 gallons on an acre basis. In 1946 and 1947, additional sprays would have increased the yields of healthy fruit substantially, but the primary object was to compare and evaluate the fungicides and spray schedules rather than to secure the maximum yield. During 1948, in Lebanon county, and during 1949, in Centre county, a sixth spray was applied but it had doubtful value.

EXPERIMENTAL RESULTS

The yields of marketable fruit and the percentage of different diseases following the various spray treatments are given in the accompanying tables in which individual items represent the average of 5 replications.

Yields in the presence of late blight.—Results for the three years when late blight was the predominant disease are shown in table 4. With no treatment, yields ranged from 0.3 to 7.6 tons, an average of 3.6 tons. The highest average yield resulting from spraying was 13.7 tons which was given by the combined schedule of ziram and tribasic copper sulfate Z-Z-Z-C-C, but it was not significantly better than the straight schedules of tribasic copper sulfate and 6-3-100 bordeaux which produced 13.2 and 12.9 tons respectively. The least effective

spray against late blight was ziram by itself which averaged 6.8 tons, although its yields in 1947 and 1948 were significantly better than no treatment. This shows that ziram has enough fungicidal capacity against late blight to hold the disease in check until a copper spray can be applied.

The alternating schedule of ziram and tribasic copper sulfate, Z-C-Z-C-Z, gave an average of 10 tons which is 3.7 tons below the Z-Z-Z-C-C schedule. This difference is likely due to the fact that late blight appeared a few days after the last spray application and the copper fungicide afforded much better protection than ziram. The 2-2-100 mixture of ziram and tribasic copper sulfate applied in 1948 gave higher yields than the Z-Z-Z-C-C schedule but the differences were not significant.

Zineb (dithane Z-78 and parzate) gave lower average yields than schedule Z-Z-Z-C-C or the straight schedules of tribasic copper sulfate and bordeaux, but only during 1947 in Centre County were any of the differences significant. In 1948 in Centre County, dithane Z-78 resulted in the highest yield of 21.8 tons. Although both forms of zineb have a tendency to slow production, September was generally warm and clear and virtually all sizeable fruit matured.

Yields with only anthracnose and early blight present.—Potential increases of yield by the control of anthracnose and early blight are less extensive than in the case of late blight. Treatments in which ziram (or ferbam) and tribasic copper sulfate were applied in varied order gave increases ranging from 0.6 to 4.7 tons, table 5. During 1949 the average increase from 13 experiments in which experiment stations cooperated was 3.29 tons for the schedule Z-C-Z-C-Z. In similar co-

Table 4.—Salable fruit when late blight was the principal disease. Centre and Lebanon Counties.

FUNGICIDE AND SPRAY SCHEDULE 1/	1946		1947		1948		Average
	Centre	Lebanon	Centre	Lebanon	Centre	Lebanon	
	tons/A	*tons/A*	*tons/A*	*tons/A*	*tons/A*	*tons/A*	*tons/A*
No treatment	0.3	0.5	3.8	4.3	7.6	5.4	3.6
Ziram (zerlate)	1.6	0.9	7.1	8.4	12.3	10.8	6.8
Tribasic copper sulfate	12.3	12.9	13.5	10.0	20.0	10.7	13.2
Ziram-tribasic copper sulfate, Z-Z-Z-C-C			15.0	10.6	18.6	10.7	13.7
Ziram-tribasic copper sulfate, Z-C-Z-C-Z	8.1	5.5	8.5	9.3	18.6	10.6	10.0
Ziram-tribasic copper sulfate, 2-2-100 mixture					20.7	11.0	
Ziram-yellow cuprous oxide, Z-Z-Z-C-C					19.5		
Bordeaux, 6-3-100	10.6	13.5	12.7	9.8	20.7	11.1	12.9
Ziram-bordeaux, Z-Z-B-Z-B					19.8	10.5	
Copper-zinc-chromate			10.3		16.4		
Zineb (dithane Z-78)	10.3	11.4	9.5	8.2	21.8	9.5	11.7
Zineb (parzate)			11.3	9.5	17.6	10.2	12.1
Cop-o-zinc					18.9	11.9	
Least significant difference (19 to 1 odds)	2.4	2.5	3.2	2.3	4.1	2.7	

1/ In the combined spray schedules, Ziram is indicated by Z, tribasic copper sulfate or yellow cuprous oxide by C and bordeaux by B.

operative experiments in 1945, the average increase was 2 tons for the schedule F-C-F-C-F. In Centre County, 1949, the 2-2-100 mixture of ziram and tribasic copper sulfate gave the very high increase of 5.5 tons, table 5. When late blight was not a factor, the schedules Z-C-Z-C-Z and Z-Z-Z-C-C gave like increases of healthy fruit.

The various combinations of ziram and tribasic copper sulfate, table 5, gave generally better results than the straight schedules of the separate fungicides, or bordeaux 6-3-100. Ziram by itself was weak against early blight while the copper fungicides by themselves caused a certain amount of injury. Yields of healthy fruit given by the two forms of zineb were nearly on a par with the combinations of ziram and tribasic copper sulfate.

The tomato spraying experiments in Lancaster County in 1949 suffered extreme drouth, and although the number of fruit was not much below normal, their size was scarcely half the usual.

Degree of late blight control.—With no treatment, the average loss caused by late blight infection of fruit was 53.1 per cent for the three destructive years, 1946-to-1948, table 6. Average loss with ziram used separately was 47 per cent, although the yield of salable fruit was nearly doubled. This apparently inconsistent result was possible because ziram enabled more fruit to attain full growth and many of them became infected just as they were maturing. Tribasic copper

Table 5.—Salable fruit per acre when anthracnose and early blight were virtually the only diseases, Centre and Lancaster Counties, 1944-45 and '49.[1]

FUNGICIDE AND SPRAY SCHEDULE	1944 Centre	1945 Centre	1949 Centre	1949 Lancaster
	tons	*tons*	*tons*	*tons*
No treatment	10.4	12.1	10.0	5.4
Ziram		14.4	12.7	5.6
Tribasic copper sulfate	11.9	14.0	11.7	5.8
Ziram-tribasic copper sulfate, Z-Z-Z-C-C			14.7	6.0
Ziram-tribasic copper sulfate, Z-C-Z-C-Z			14.7	
Ziram-tribasic copper sulfate, 2-2-100 mixture			15.5	6.0
Ziram-tribasic copper sulfate, 1-2-100 mixture			14.6	6.3
Ziram-tribasic copper sulfate, sliding-scale mixture			14.9	5.9
Ziram-copper-zinc-chromate Z-Z-Z-Czc-Czc			12.6	
Bordeaux, 6-3-100	12.1	12.5	12.4	
Ziram-bordeaux, Z-Z-Z-B-B			12.7	
Ferbam (fermate)	12.4	14.3		
Ferbam-tribasic copper sulfate, F-C-F-C-F	12.1	14.1		
Zineb (dithane Z-78)			14.6	5.5
Zineb (parzate)			15.1	
Cop-o-zinc			12.9	5.9
Bioquin			15.7	
Manganese . . . carbamate			17.4	
Least significant difference (19 to 1 odds)	not sig.	not sig.	2.9	not sig.

1/ A sixth application of the fungicides was made in 1949.

In 1949, the tomato experimental plots in Lancaster County suffered extreme drouth, and although the fruits were not much below normal in number, they grew to scarcely half usual size

Fig. 6.—Tomato foliage and fruit on September 25, 1949, when sprayed with maganese ethylene bis dithiocarbamate. The plant was undesirably vegetative for the time of year. Production was unusually great but too large a proportion of the fruit did not mature.

sulfate and bordeaux applied separately resulted in the least fruit infection, or averages of 10.6 and 10.7 per cent respectively. The schedule Z-Z-Z-C-C permitted 14.1 per cent average infection, but the schedule Z-C-Z-C-Z the much greater amount of 30 per cent. This contrast in loss reveals the low efficiency of ziram as compared with tribasic copper sulfate as a last application before late blight attacks.

Table 6.—Control of late blight shown by fruit infection, Centre and Lebanon counties, 1946-48, inclusive.

Fungicide and Spray Schedule	1946		1947		1948		Average
	Centre	Lebanon	Centre	Lebanon	Centre	Lebanon	
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
No treatment	97.0	98.0	69.0	28.3	15.0	11.1	53.1
Ziram (zerlate)	86.0	84.0	52.2	28.6	13.2	9.0	47.0
Tribasic copper sulfate	27.0	6.0	17.5	4.4	2.2	6.0	10.6
Ziram-tribasic copper sulfate, Z-Z-Z-C-C			21.5	8.3	5.1	7.5	14.1
Ziram-tribasic copper sulfate, Z-C-Z-C-Z	55.0	51.0	47.1	11.7	11.2	7.0	30.0
Ziram-tribasic copper sulfate, 2-2-100 mixture					4.0	9.4	
Ziram-yellow cuprous oxide					1.2		
Bordeaux, 6-3-100	25.0	8.0	16.5	2.0	5.9	6.7	10.7
Ziram-bordeaux					5.1	7.1	
Copper-zinc-chromate			29.6		7.5		
Zineb (dithane Z-78)	27.5	14.3	31.5	13.5	8.8	10.7	17.7
Zineb (parzate)			41.0	15.2	11.0	10.2	19.3
Cop-o-zinc					6.6	7.4	

Table 7.—Control of anthracnose shown by infected fruit and disease reduction below the average of no treatment, Centre and Lebanon Counties, 1945 to 1949, inclusive.

Fungicide and Spray Schedule	1945		1947		1948		1949		Average	Disease Reduction	
	Cen.	Leb.	Cen.	Leb.	Cen.	Leb.	Cen.	Leb.		Penna.	Coop. States 1/
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
No treatment	13.5	23.0	20.0	24.2	28.5	12.7	18.0	10.2	19.0	0	0
Ziram (zerlate)	4.3	8.0	5.9	4.9	3.6	2.4	2.8	0.8	4.1	78.0	74.6
Tribasic copper sulfate	6.7	11.0	11.4	11.3	12.4	10.0	6.4	2.3	8.9	47.0	46.0
Ziram-tribasic copper sulfate, Z-Z-Z-C-C			5.8	7.8	8.2	4.1	2.9	0.8	4.9	74.0	
Ziram-tribasic copper sulfate, Z-C-Z-C-Z			4.3	6.1	4.1		3.8		4.6	77.0	70.5
Ziram-tribasic copper sulfate, 2-2-100 mixture					4.4		2.5	0.9			
Ziram-tribasic copper sulfate, 1-2-100 mixture							2.3	1.3			
Ziram-tribasic copper sulfate sliding-scale mixture							2.6	0.9			
Ziram-yellow cuprous oxide, Z-Z-Z-C-C					8.5						
Bordeaux, 6-3-100	4.6	13.3	4.6	10.7	8.5		6.0		7.9		
Ziram-bordeaux					3.1	5.2	5.8		4.7	76.5	
Ziram-crag, Z-Z-Z-crag-crag-crag							5.9				
Zineb (dithane Z-78)			8.2	12.1	3.1	3.3	5.1	0.8	5.4	71.0	61.0
Zineb (parzate)			2.5	14.5	5.2	7.1	5.3		6.9	67.0	66.0
Cop-o-zinc					14.1	12.6	10.6	3.7	10.2	45.0	
Bioquin							2.9				
Manganese . . . carbamate							4.3				
Least significant difference at 19 to 1 odds	2.8	4.5	5.3	4.8	6.4	2.3	2.8	1.2			

1/ Average percentage of disease reduction in cooperating states was computed from data in Plant Disease Reporter (see bibliography); also from data of the 3rd. Ann. Rpt. Special Committee Amer. Phytopath. Soc. on the coordination of field tests with new fungicidal sprays and dusts with reference to results obtained in 1949. May, 1950.

Anthracnose results were obscured by late blight in 1946.

Late blight losses in the case of dithane Z-78 and parzate averaged 17.7 and 19.3 per cent respectively. These losses are considerably greater than those resulting from use of tribasic copper sulfate or bordeaux. To overcome this disadvantage, manufacturers recommend that dithane Z-78 and parzate be applied every 5 to 7 days instead of every 10 days when late blight threatens. It is probable that a sixth application of all fungicides would have cut the respective losses materially in 1946 and 1947.

Degree of anthracnose control.—This disease caused an average loss of 19 per cent on the unsprayed experimental plots during the four years in which data were obtained, table 7. Anthracnose damage was obscured by late blight in 1946. A loss of 19 per cent is considerably less than that sometimes occurring in the older tomato growing areas in which infection of fruit may reach 30 to 40 per cent when control measures are not undertaken. It may be noted that anthracnose reached 10.2 per cent under the drouth conditions in the Lancaster County plots in 1949 in the case of no treatment.

A perusal of the data in table 7 shows that ziram gives the best and most consistent control of anthracnose. This fungicide reduced the average fruit infection to 4.1 per cent in the 8 series of experiments in Pennsylvania. This represents a reduction in disease of 78 per cent, or an efficiency of 78 per cent. In the cooperative experiments conducted by state experiment stations, the average efficiency of ziram was 74.6 per cent. Average anthracnose infection with tribasic copper sulfate in Pennsylvania was 8.9 per cent, giving an efficiency of only 47 per cent. In the cooperative experiments, the efficiency of tribasic copper sulfate was 46 per cent. Bordeaux surpassed tribasic copper sulfate in anthracnose control showing 58 per cent efficiency in Pennsylvania and 60 per cent efficiency in the cooperative experiments. Dithane Z-78 and parzate have 71 and 61 per cent efficiency, respectively, in Pennsylvania and 67 and 66 per cent, respectively, in the cooperative experiments. These data indicate that the zineb materials are approximately 10 per cent less efficient than ziram in anthracnose control.

The schedules Z-Z-Z-C-C and Z-C-Z-C-Z of ziram and tribasic copper sulfate control anthracnose almost as efficiently as ziram alone, the differences being as a rule nonsignificant. The respective averages of infection in Pennsylvania were 4.9 and 4.6 as compared with 4.1 per cent. These represent efficiencies of 74 and 77 as compared with 78 per cent. This schedule Z-C-Z-C-Z had an efficiency of 70.5 per cent in the cooperative experiments.

The 1-2-100, the 2-2-100 and the sliding-scale mixture of ziram and tribasic copper sulfate had an efficiency similar to pure ziram in the 1949 experiments, table 7. Anthracnose was restricted to a range of 0.8 to 2.6 per cent while the averages for no treatment were 10.2 and 18 per cent according to locality.

Control of early blight upon fruit.—None of the fungicides or the combinations of them proved very effective in reducing fruit infection by *Alternaria solani.* The apparent reason for this is that attack is restricted largely to fruit which matures late when natural resistance is low and fungicidal residues have become dissipated. The better spray treatments reduced infections approximately half in comparison with no treatment, table 8. In the case of ziram by itself, however, infections were often more numerous than no treatment. This fungicide favored the development of a greater number of fruit but provided insufficient protection near the close of the season. Several of the sprays were significantly better than no treatment, but differences between the spray treatments were not significant except for ziram in comparison with certain others.

Defoliation by early blight.—The chief benefit arising from the control of early blight is the prevention of premature defoliation and its consequent ill effect upon the development of fruit. The retention of healthy, vigorous foliage until late in the season is unessential; on the other hand it may be undesirable when it tends to slow production. The best comparison of the different spray treatments in prevention of defoliation by early blight was obtained in 1949 in Centre

Table 8.—Fruit infected with early blight infection, *Alternaria solani*, 1948-49.

Fungicide and Spray Schedule	1948 Centre	1948 Lebanon	1949 Centre	Average
	per cent	*per cent*	*per cent*	*per cent*
No treatment	12.1	8.2	16.0	12.1
Ziram (zerlate)	19.8	6.2	18.5	14.8
Tribasic copper sulfate	9.0	3.6	11.6	8.1
Ziram-tribasic copper sulfate, Z-Z-Z-C-C	9.3	4.0	9.6	7.6
Ziram-tribasic copper sulfate, Z-C-Z-C-Z	8.9		8.5	8.7
Ziram-tribasic copper sulfate, 1-2-100 mixture			10.3	
Ziram-tribasic copper sulfate, 2-2-100 mixture	4.7	2.9	10.5	6.0
Ziram-tribasic copper sulfate, sliding-scale mixture			8.2	
Ziram-yellow cuprous oxide	7.4			
Bordeaux, 6-3-100	3.7	5.1	12.8	7.2
Ziram-bordeaux, Z-Z-B-Z-B	6.0	5.2	5.6	5.6
Ziram-crag Z-Z-Z-crag-crag-crag			13.7	
Zineb (dithane Z-78)	4.7	4.4	9.0	6.0
Zineb (parzate)	8.1	4.1	10.4	7.5
Cop-o-zinc	6.0	3.2	16.7	8.6
Bioquin 1			13.1	
Manganese . . . carbamate			6.3	
Least significant difference at 19 to 1 odds	7.1	not sig.	5.1	

County when leaf infections became profuse upon unsprayed plants in late summer and were not obscured by late blight. Defoliation of unsprayed plants reached 76 per cent by September 20. The least defoliation at this date occurred with the zineb and the manganese ethylene bis dithiocarbamate treatments, the range for these being only 12 to 18 per cent, table 9. The proportion of mature fruit will show later, however, that this degree of foliage retention was beyond desirable limits. On the basis of ultimate results, the treatments having intermediate defoliation on September 20 were the most desirable, particularly those including both ziram and tribasic copper sulfate in which about 40 per cent of the foliage was lost.

Ziram in a straight schedule did not preserve the foliage well enough, 69 per cent having been destroyed by early blight by September and this is evident in the high percentage of fruit infections. It may be noted in table 9 that the average of data in Pennsylvania and

Table 9.—Defoliation caused by early blight, Centre County, 1946 to 1949, inclusive.[1]

Fungicide and Spray Schedule	1946	1947	1948	1949	Penna.	Average Cooperating States
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
No treatment	57	35	45	76	53	69
Ziram (zerlate)	25	9	22	69	32	40
Tribasic copper sulfate	20	6	6	40	18	32
Ziram-tribasic copper sulfate, Z-Z-Z-C-C		10	11	51	24	
Ziram-tribasic copper sulfate, Z-C-Z-C-Z	18	12	11	43	21	33
Ziram-tribasic copper sulfate, 2-2-100 mixture			6	42	24	
Ziram-tribasic copper sulfate, 1-2-100 mixture				41		
Ziram-tribasic copper sulfate sliding-scale mixture				40		
Ziram-yellow cuprous oxide			10			
Bordeaux, 6-3-100	20	8	6	35	17	25
Ziram-bordeaux	16		7	35	20	
Ziram-copper-zinc-chromate, Z-Z-Z-Czchr-Czchr-Czchr				50		
Copper-zinc-chromate		14	11			
Zineb (dithane Z-78)	18	5	6	12	10.2	35
Zineb (parzate)		4	6	18	9.3	30
Cop-O-Zinc			6	45	27	27
Bioquin 1				41		
Manganese . . . carbamate				15		
Least significant difference at 19 to 1 odds			3.0	13.3		

1/ In 1946, 1947 and 1948, data upon defoliation by early blight were taken the third week of August or at the first signs of late blight. In each of these years, late blight completed defoliation of unsprayed plants within 10 days after its appearance. In 1949, data upon defoliation by early blight were taken September 20.

from cooperating state experiment stations give rather similar ranking to the spray treatments in respect to defoliation. In figures 4, 5 and 6, the condition of the foliage on September 25 is shown respectively for no treatment, zineb (dithane Z-78) and manganese ethylene bis dithiocarbamate. The most desirable condition of the foliage was shown by the 1-2-100 mixture of ziram and tribasic copper sulfate, frontispiece, although other spray schedules including these two fungicides were quite similar.

Rate of production and proportion of mature fruit.—Fungicides have varied effects upon plants aside from the prevention of disease. Some effects are toxic or injurious in nature as heretofore noted, but others are manifest by enhanced vegetative development, which may be in part an indirect result of disease prevention. Undue vegetative development is often attended by slowed fruit production and delayed harvest. A great amount of fruit may be set but a large proportion of it may not have time to mature before frost.

The proportion of fruit which attains full maturity is of much concern to growers who supply canners in areas having short growing seasons. Fruit which matures in warm weather is superior in quality to that which matures in the cool fall, particularly for the making of tomato juice. For this reason, spray treatments which prevent disease effectively yet do not retard the rate of production are preferable.

Experimental results were unaffected by late blight in 1949 and they afford a good comparison of the different spray treatments in respect to the proportion of mature, immature, and cull fruit. The tomato crop in Centre County was late but the first frost did not occur until the end of September when most of the foliage was killed. The remaining partially ripe and green fruit of marketable size was gathered and comprised the sixth picking of the season. This fruit was salable upon a fresh vegetable market but was wholly unfit for canning.

Table 10 is a record of the 1949 production of the experimental plots in Centre County, giving in tons first the amount of healthy fruit, then the portion of this which matured, the portion of mature in the first four pickings and the portion of immature. Culls are recorded as percentages so that results in 1949 would be comparable with those in the three late blight years. To facilitate comparison of the different spray treatments, the proportions of healthy and diseased fruit in successive pickings are shown graphically in figure 7. Mature fruit is confined to the first five pickings and is indicated by the absence of shading in each diagram. Immature fruit constituted the sixth picking and is denoted by line shading while diseased fruit (culls) is denoted by black.

Most desirable spray treatments.—According to the data of table 10 and results depicted in figure 7, the highest ranking spray treatment in 1949 was the 1-2-100 mixture of ziram and tribasic copper sulfate which had 12.4 tons of mature fruit, of which 10 tons were in the first

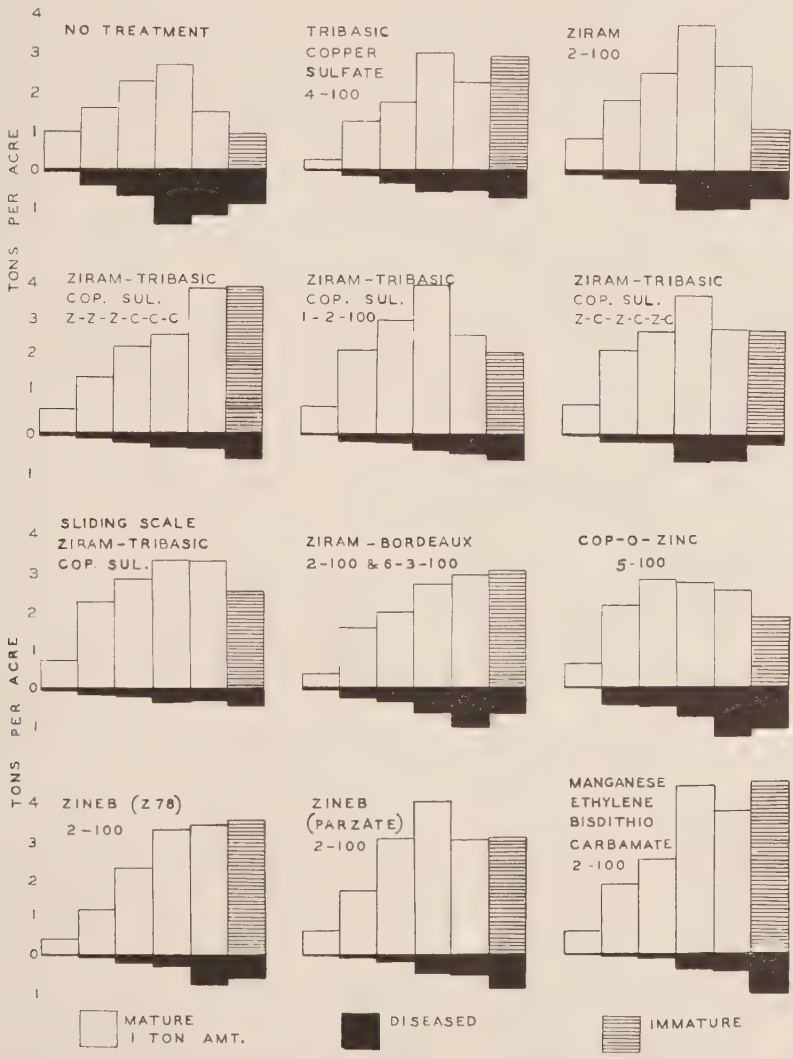

Fig. 7.—Proportions of healthy mature, healthy immature, and diseased fruit in six successive pickings in the different spray treatments, 1949.

four pickings and only 2.2 tons were immature. The sliding scale mixture, the 2-2-100 mixture, the alternating schedule Z-C-Z-C-Z-C and parzate follow in close order, however, with 12 or more tons of mature fruit but with somewhat less in the first four pickings and slightly more immature fruit. Maganese ethylene bis dithiocarbamate and bioquin 1 are better in some respects than the preceding but these fungicides are

Table 10.—Proportion of healthy, mature, mature in the first four pickings and immature fruit; also the percentage of culls, Centre County, 1949.

Fungicide and Spray Schedule	Total Healthy Fruit	Mature Fruit	Mature in 1st 4 Pickings	Immature* Fruit	Culls in 1949	Av. Per Cent Culls in 3 Yrs. of Late Blight
	tons	*tons*	*tons*	*tons*	*per cent*	*per cent*
No treatment	10.0	9.1	7.6	0.9	31.8	63.5
Ziram (zerlate)	12.7	11.6	8.9	1.1	21.6	54.4
Tribasic copper sulfate	11.7	8.6	6.3	3.1	18.8	25.1
Ziram-tribasic copper sulfate, Z-Z-Z-C-C-C	14.7	11.0	7.0	3.7	11.4	26.1
Ziram-tribasic copper sulfate, Z-C-Z-C-Z-C	14.7	12.0	9.3	2.7	11.8	36.6
Ziram-tribasic copper sulfate, 1-2-100 mixture	14.6	12.4	10.0	2.2	13.3	
Ziram-tribasic copper sulfate, 2-2-100	15.5	12.4	9.3	3.1	12.4	
Ziram-tribasic copper sulfate sliding-scale mixture	14.9	12.5	9.2	2.4	10.8	
Ziram-crag Z-Z-Z-crag-crag-crag	12.6	9.5	6.9	3.1	19.4	
Bordeaux, 6-3-100	12.4	8.8	6.0	3.6	16.0	21.9
Ziram-bordeaux	12.7	9.7	6.8	3.0	20.6	20.9
Zineb (dithane Z-78)	14.6	10.9	7.5	3.7	13.1	30.2
Zineb (parzate)	15.1	12.0	9.1	3.1	15.4	30.7
Cop-O-Zinc	12.9	10.8	8.3	2.1	25.4	25.5
Bioquin 1	15.7	12.6	9.5	3.1	14.2	
Manganese . . . carbamate	17.4	12.9	9.2	4.5	12.2	

*Immature fruit included healthy green and partially reddened specimens of marketable size.

not generally available at present. The schedule Z-Z-Z-C-C-C is below the other combinations of ziram and tribasic copper, having only 11 tons of mature fruit, 7 tons in the first four pickings and 3.7 tons immature. Apparently the three successive applications of tribasic copper sulfate at 4-100 strength during relatively dry weather slowed production.

Tribasic copper sulfate and bordeaux in straight schedules gave the lowest proportions of mature fruit, or 8.6 and 8.8 tons respectively of which 6.3 and 6 tons were in the first four pickings. Ziram-bordeaux and dithane Z-78 are of relatively low rank, having respectively 9.7 and 10.9 tons of mature fruit and 6.8 and 7.5 tons in the first four pickings. These four spray treatments are high in immature fruit, ranging from 3 to 3.7 tons.

Ziram in a straight schedule gave virtually no evidence of slowed production, having 11.6 tons mature and only 1.1 tons immature fruit in comparison with no treatment which had 9.1 tons mature and 0.9 tons immature. Ziram by itself must be discounted considerably for low total yield and a high amount of disease.

In figure 8 the production rates of four spray treatments in comparison with no treatment are shown by curves which represent the aggregate yields after each of six pickings. These four spray treatments comprise those which have been used most commonly in Pennsylvania in recent years according to the greater or lesser importance of late blight. Each curve is intersected by a line representing the frost date, and this divides the mature from the immature fruit. Ziram-tribasic copper sulfate maintains the lead from the second picking to the end of the season. This highest curve really represents the average of the four different combinations of ziram and tribasic copper sulfate giving

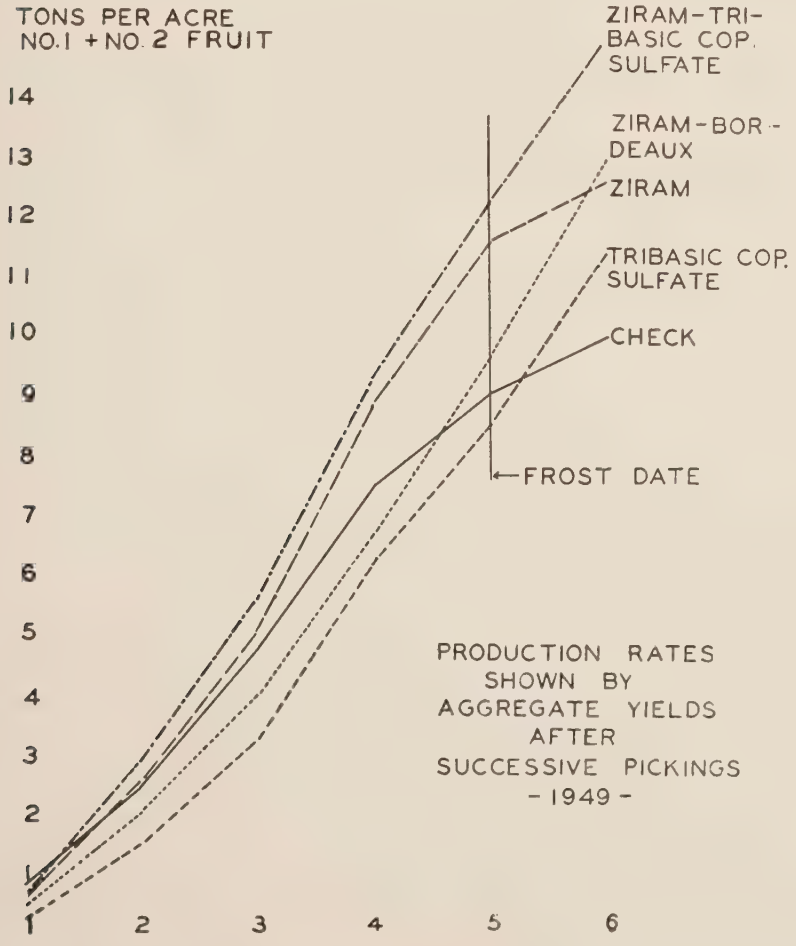

Fig. 8.—Production of tomatoes from comparable plots as a result of four spray treatments used in Pennsylvania during recent years.

best yields as recorded in table 9, as each would assume essentially the same position in the graph. Ziram in a straight schedule holds second place when only mature fruit is considered, but it is surpassed by ziram-bordeaux when both mature and immature fruit are included. Ziram-bordeaux is below the check until the fifth picking. Tribasic copper sulfate is below the check upon the basis of mature fruit but surpasses the check if immature fruit is included. This low position of tribasic copper sulfate shows that it definitely retarded production when applied at 4-100 strength under the relatively dry weather conditions of mid-summer in 1949.

Cull fruit.—The percentages of cull fruit for 1949 and the averages for the three years of late blight are given in the last two columns of table 10. In the absence of late blight as in 1949, the schedules including ziram and tribasic copper sulfate were lowest in the proportion of cull fruit with a range of 10.8 to 13.3 per cent. Ziram by itself resulted in a high percentage of culls due to its weakness against early blight. It had 21.6 per cent as compared with 31.8 per cent for no treatment. Dithane Z-78 and parzate as well as tribasic copper sulfate and bordeaux are intermediate in the proportion of culls, the range being from 13.1 to 18.8 per cent.

The proportions of culls during the late blight years are in marked contrast in most instances to those of 1949. With late blight present, the lowest proportions are usually given by bordeaux and tribasic copper sulfate, although ziram bordeaux and the ziram-tribasic copper schedule Z-Z-Z-C-C are almost equally low, all of these being within the range 20.9 to 26.7 per cent. The alternating schedule Z-C-Z-C-Z had 36.6 per cent culls because it ended with ziram which did not provide enough protection against late blight. Ziram by itself shows its inefficiency against late blight with 54.4 per cent culls as compared with 63.5 per cent for no treatment.

Maganese ethylene bis dithiocarbamate.—This is a promising fungicide which has received experimental trial at a number of State Experiment Stations. In Pennsylvania, it gave outstanding control of early blight as well as good control of anthracnose during 1949. The results are included here because they furnish an excellent example of enhanced vegetative development and high production, table 10 and figure 6. Total production of healthy fruit was 17.4 tons, but only 12.9 tons matured, an amount only 0.5 tons more than in the case of the 1-2-100 mixture of ziram and tribasic copper sulfate. Maturity tended to be late, the proportion of immature fruit being 4.5 tons. The fungicide would seem best adapted to a locality having a long growing season in order to reap the full benefit of promoted growth. This fungicide is not generally available.

Cop-O-Zinc.—This fungicide contains 42 per cent copper and 11 per cent zinc on a metal basis. It apparently promotes growth and heavy development of fruit, but the proportion which was healthy was below that of several other treatments. Its control of anthracnose is relatively low while its control of early blight declines at an early period in fall. This is shown by 25.4 per cent of culls, table 10.

Bioquin 1.—The results obtained in Pennsylvania in 1949 with this fungicide are virtually on a par with those obtained with the combinations of ziram and tribasic copper sulfate, table 10. This material is not on the market as yet.

Crag.—This fungicide has given good control of disease upon potatoes. Upon tomatoes, it has not given results as good as some other fungicides apparently because it was not used in great enough strength. The strength of mixture should be increased, being used at 3 to 4 lbs. to 100 gallons to obtain best control according to results in certain other states.

Increased production of tomatoes for canning.—Table 11 contains data upon acreage, yield, value and the increase due to the application of fungicides in Pennsylvania from 1946 to 1949 inclusive, or from the beginning to the present date of the current disease control program. Except for 1946, when the majority of growers were unprepared for the attack of late blight, the average yield per acre has been at a higher level than during the previous ten-year period of 1936 to 1945. In 1947, 1948 and 1949, average yield per acre ranged from 6.5 to 8.2 tons, whereas the average yield from 1936 to 1945 was 5.4 tons. In 1949, a somewhat greater tonnage was harvested upon an acreage which was 20 per cent less than in the period 1936 to 1945. This does not take into consideration improved quality which is an important result of spraying. In the last four years, disease control has been estimated to have increased the value of the tomato crop 4,502,968 dollars, the cost of spraying or dusting not being deducted.

Table 11.—Yields, prices and disease losses* in canning tomatoes in Pennsylvania, 1936-1949, inclusive.†

Year Average	Average Acreage	Average Tons Per Acre	Tons Harvested	Average Price Per Ton	Crop Value	Actual Loss With Some Growers Spraying	Est. Loss if no Sprays Had Been Applied	Amount Crop Sprayed and Dusted	Saved by Spraying	
	acres	*tons*	*tons*	*value*	*value*	*per cent*	*per cent*	*per cent*	*tons*	*value*
1936-1945	25,200	5.4	131,600					Almost none		
1945						10	10	Almost none		
1946	34,200	2.7	99,200	$34.90	$3,450,000	50	75	26	49,600	$1,725,000
1947	27,900	6.7	192,500	31.00	5,968,968	20	35	60	36,000	1,116,968
1948	19,400	8.2	159,100	30.90	4,916,000	10	35	75	44,300	1,355,000
1949	20,500	6.5	133,200	Est. 30.00	3,996,000	.5	8	85	8,800	306,000
									139,000	$4,502,968

*Mainly late blight.

†Data assembled by Dr. R. S. Kirby, Extension Plant Pathologist, The Pennsylvania State College.

DISCUSSION

Although much variation occurs in the kind and amount of tomato disease according to year, weather and locality, the experimental results show that the specific nature of the several available fungicides makes it possible to combat the diverse conditions with a high degree of success. The choice of a spray treatment should be in the light of current or prospective conditions insofar as these can be foreseen.

In the presence of late blight which is usually attended by rainy weather, the use of strong long-lasting fungicides like bordeaux or 4-100 tribasic copper sulfate are justified until the threatening period is past. When there is no danger of late blight it may often be advisable to reduce the strength or the number of applications of copper fungicides lest plant growth be retarded and a large porportion of immature fruit result.

When anthracnose is the only disease, ziram in a straight schedule may be a sufficient treatment. In view of disease conditions as they have prevailed over many former years, both anthracnose and early blight are likely to be the common diseases. Experimental results then show that combined schedules or mixtures of ziram and fixed copper compounds are the most satisfactory when disease control, crop yield and the proportion of mature fruit are considered. The 1-2-100 mixture of ziram and tribasic copper sulfate has given superior results without evidence of plant injury and offers a simple and convenient spray treatment. Other combinations have given approximately as good results.

Three applications of ziram followed by two or more of tribasic copper sulfate gave results equal or better than straight schedules of the copper compounds in the late blight years, but this same treatment may reduce the proportion of mature fruit in the absence of late blight. Hence the timing as well as the amount of copper material in the treatment requires consideration.

The zineb materials have shown important tendency to promote vegetative growth which is attended by delay of harvest and large proportions of immature fruit. Use of fungicides with such tendencies should be considered in reference to the length of the season and the probability that the heavy development of fruit will have time to mature.

SUMMARY

This bulletin contains data covering six years in evaluation of different fungicides as tomato sprays for control of late blight, early blight, and anthracnose, and for increase of salable fruit. Data concerning rate of production and the proportion of mature fruit resulting from different spray treatments in 1949 are included.

As a direct comparison, each fungicide was applied separately or in a straight schedule of 5 applications, or in some cases 6 applications. Other schedules consisted of ziram (zerlate) and bordeaux, ziram and tribasic copper sulfate, or ziram and another fungicide, applied in varied sequence. Three different tank mixtures of ziram and tribasic copper sulfate also were tested.

Ziram applied separately gave the best and most consistent control of anthracnose, or 78 per cent average reduction of fruit infection in Pennsylvania experiments and 74.6 average reduction in trials of various cooperating state experiment stations. Spray schedules including ziram and another fungicide were only slightly less effective against anthracnose in comparison to ziram used separately. Ziram was the least effective fungicide against late blight, and was relatively weak in prevention of defoliation and fruit infection by early blight.

Bordeaux and tribasic copper sulfate (or fixed copper fungicides) were the most effective in control of late blight. Three applications of ziram followed by two or more of tribasic copper sulfate, however, gave equally good or better yields of salable fruit during the severe late blight years, the average being 13.7 tons as compared with 3.6 tons with no treatment. The alternating schedule of ziram and tribasic copper sulfate was not equally good because the period between copper sprays was too long to give efficient control of late blight. The average yield of this schedule was 10 tons.

Zineb (parzate and dithane Z-78) was somewhat less effective than copper fungicides in the control of late blight when applied at 10-day intervals, although its use was generally profitable in the late blight years, the average yield being 11.9 tons of salable fruit. Zineb was especially effective against early blight and about 10 per cent less effective than ziram against anthracnose.

As a rule, spray treatments which included ziram and tribasic copper sulfate were superior to a single fungicide when control of disease, yield, rate of production and the proportion of mature healthy fruit are considered. In 1949 when late blight was absent, a 1-2-100 mixture of ziram and tribasic copper sulfate yielded the highest proportion of mature healthy fruit, or 12.4 tons of which 10 tons were in the first four pickings. These quantities were 73 and 60 per cent respectively of total production. Following in close order with more than 9 tons in the first 4 pickings were a sliding-scale mixture, a 2-2-100 mixture and

the alternating schedule of ziram and tribasic copper sulfate, and then parzate.

Bordeaux and tribasic copper sulfate in straight schedules were lowest in the proportion of mature healthy fruit during 1949, having 8.8 and 8.6 tons respectively, of which 6 and 6.3 tons were in the first four pickings. Corresponding results for other spray treatments were intermediate. Among these was 3 applications of ziram followed by 3 applications of tribasic copper sulfate, which resulted in only 11 tons of mature healthy fruit and only 7 tons in the first four pickings. This shows the retarding effect of successive sprays of the copper at 4-100 strength under moderately dry conditions. No treatment yielded 9.1 tons of mature healthy fruit with 7.6 tons in the first four pickings.

The zineb materials showed an important tendency to promote vegetative growth, and although fruit production was heavy, maturity was slow and the proportions of immature fruit were high. Differences in the proportion of mature fruit are fungicidal effects which are largely aside from the prevention of disease, being due in some cases to injury and retarded growth but in others to enhanced vegetative development and slowed fruit production. The results in general show the importance of fitting spray treatments to different conditions of disease, weather, and season.

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